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CONSERVATION PLANNING FOR WATER QUALITY CONCERNS, RELATED TO PHOSPHOROUS ISSUES ASSOCIATED WITH THE APPLICATION OF ORGANIC WASTE

The purpose of this Technical Note is to provide consultants and experienced planners with a tool to aide in determining land treatment needs and manure management measures on land application sites. The P-Index (http://cnmp.unl.edu/cnmpsoftware2.html) to be used is developed as a spreadsheet. This tool is also available on eFOTG under Section IV, Tools, Phosphorus_Index_2006. This tool will assess the relative risk of phosphorus (P) movement into surface water from a manure application site, identify appropriate BMPs, and identify critical factors that impact P loss.

Degradation of surface water quality from (P) in runoff and sediment is an increasing water quality concern. Excessive P in surface water can result in excessive algae and plant growth causing a depletion of oxygen for fisheries. This Technical Note is the Background Paper and Users Guide developed in conjunction with the new P-Index. The new P-Index is an adaptation of the multiplicative Iowa P-Index

This tool can also be used to compare the relative risk of P loss of one site versus another. Factors such as P soil test levels, P management practices (rate, timing and method of application), runoff, soil erosion, sediment delivery and other factors impact the potential for P loss. Reducing runoff and erosion is also important to maximize nutrients available for crops. Appropriate best management practices (BMPs) to reduce the risk of P loss can be identified after determining the most critical factors that impact P loss. Practices and management measures identified through the use of this tool need to be incorporated into Comprehensive Nutrient Management Plans (CNMPs).

THE NEBRASKA PHOSPHORUS INDEX (2005): BACKGROUND AND USERS GUIDE

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This publication provides the basis and procedure for use of phosphorus (P) index to assess risk of P delivery from agricultural land to surface waters. The P index is intended for planning as well as regulatory and educational purposes.

Phosphorus is an essential nutrient for crop growth and for the growth of aquatic vegetation. Phosphorus, either in inorganic form such as with fertilizer or in organic form as with animal manures, often needs to be applied to the land for optimal crop growth. An important by-product of animal feeding is manure that contains P. Land application of manure can be beneficial to crop production but can result in increased risk of P loss to surface waters. Phosphorus indexes are tools for the assessment of the potential for P delivery from agricultural lands to surface waters. Operators of large concentrated animal feeding operations (CAFOs) in Nebraska (by Jan. 1 2007) will be required to apply a P index to assess the risk of P delivery to surface waters from each field receiving manure.

The Nebraska P Index (2005) is a tool for risk assessment, land management planning, education of factors contributing to P loss, and regulation of P application to agricultural land. The Nebraska P Index (2005) was developed through the integration of concepts from an earlier Nebraska P index (Kucera, 2000; revised in 2004; (http://www.ne.nrcs.usda.gov/technical/CNMP/NE_CNMP_Livestock.html).), an index developed for Iowa (Iowa NRCS, 2004; http://www.ia.nrcs.usda.gov/technical/Phosphorus/phosphorusstandard.html); and recent research findings.

The P index considers source and transport factors to estimate P loss to surface waters. The source factors allow assessment of the quantity and forms of P present at the site (Table 1). The transport factors allow assessment of the potential for transport of P from the site to a water body.

The P index was designed to be used on the basis of a whole field or management units within a field. In many fields, risk of P loss is often considerably greater for part of a field than for the whole field and it may be economically and environmentally advantageous to do the P loss risk assessment by zones within fields.

The Structure of the Nebraska P Index (2005)

The worksheets

The P index (http://cnmp.unl.edu/cnmpsoftware2.html) is developed as a spreadsheet to ease calculations. The spreadsheet program contains 16 worksheets. Tabs to these worksheets are found at the bottom of the screen. Users of the P index do not need to be familiar with most of these worksheets and the full P index evaluation can be done with the **Nebraska P-Index** worksheet accessed with the leftmost tab. Beginning with the left-most tab, these worksheets are as follows.

1. **Nebraska P-Index** is the worksheet of greatest concern to the user. All data is entered here and the results are presented.
2. **Summary** contains the summarized results of P index evaluations for up to 6 fields.

3. **Ephemeral** contains two tools for estimating sediment loss due to ephemeral gully erosion. The user can access this from the **Nebraska P-Index** worksheet.
4. **Landform Regions** contains a list and map of Nebraska showing the regions. The user can access this from the **Nebraska P-Index** worksheet.
5. **Lookups** contains information that the P index accesses in performing calculations.
6. **Soil properties** contain information for all soil series of the state.
7. **SDR** contains information that the P index accesses in calculating the sediment delivery factor.
8. **RCN** contains soil and land use information used in calculating the runoff curve number.
9. **Landform** assigns landform values to counties.
10. **Precip Factor** contains a value for each county indicating the runoff volume potential.
11. **Erosion STP Factors** relates soil test P to particulate P in runoff.
12. **Runoff STP & P Rate Factors** relates soil test P and the rate and method of P application to dissolved P in runoff.
13. **Counties** are a listing of the counties with a number assigned.
14. **SoilsByCountyIndex** contains information relative to the next worksheet.
15. **SoilsByCounty** contains soil series by counties.
16. **Code 393** is the NRCS standard for filter strips. The user can access this from the **Nebraska P-Index** worksheet.

The components

The P index has erosion and runoff components which integrate source and transport factors to give component risk values. The irrigation and manure components modify the risk values for the erosion and runoff components. Information is entered, and results are reported, in the leftmost worksheet, **Nebraska P-Index.** The sum of the risk value of both the erosion and runoff each component is the P index score.

The **erosion component** (potential delivery of sediment P to surface water) gives an approximate estimate of the P delivered in sediment (lb P/ac/yr) which will eventually be available for use by aquatic vegetation (Mallarino et al., 2002). It assumes that 70% of sediment P will become bio-available to aquatic vegetation over a long period of time. The erosion component is a function of 6 factors.

1. Rate of sheet and rill erosion is estimated in tons per acre per year. This erosion rate may be best estimated with RUSLE2 but other means of estimating erosion, such as the Universal Soil Loss Equation or RUSLE1, may be acceptable.
2. Ephemeral gully and classical gully erosion (t/Ac/yr) are estimated and prorated over the whole field or management unit. The P index provides two tools for estimation of ephemeral gully erosion.
3. Sediment delivery ratio considers land form and distance from the center of the field or management unit and the point where runoff water concentrates in natural and man-made conveyances outside the field that direct runoff water into intermittent or perennial streams, lakes or other water bodies.
4. Credit is given to sediment trap efficiency of conservation practices.
5. P enrichment is estimated considering tillage, surface cover, and buffer strip width.
6. Soil test P (STP; Bray-P1, Mehlich 3, or Olsen) is used to estimate total soil P (TP). The equations for medium and fine textured soils are TP = 400 + (2.5 x STP) when using the Bray-P1 or Mehlich-3 soil test and TP = 400 + (3.6 x STP) when using the Olsen test for medium and fine texture soils. For sandy soils, TP = 250 + (2 x STP) with the Bray-P1 or Mehlich-3 and TP = 250 + (3 x STP) with the Olsen P.

The **runoff (water loss) component** estimates the amount of dissolved P (orthophosphate P and other dissolved P) delivered with runoff water (Mallarino et al., 2002). It is a function of:

1. mean county precipitation and percent of rainfall events that are greater than 0.75 inch;
2. runoff curve numbers which are calculated from soil property information, land use, and management practices;
3. an estimate of dissolved soil P (DP) estimated from soil test P where DP = 0.05 + (STP x 0.005); and,
4. P application rate, time and method.

The **irrigation component** considers sprinkler and furrow irrigation. The runoff P risk factor is increased by 10% with sprinkler irrigation due to increased runoff potential should a heavy rainfall event occur when the soil is wet following irrigation. Risk with furrow irrigation is primarily due to increased erosion potential and the irrigation erosion factor is determined considering soil erodibility, rate of water flow, furrow slope, use of polyacrylamide (PAM), and the presence of a re-use pit for recycling of irrigation water (Table 2).

The erosion and runoff components are adjusted by the manure component which accounts for beneficial effects on soil properties due to previous applications of manure. This is used if erosion is estimated by means other than RUSLE2; RUSLE2 already gives credit to this benefit. The values for the erosion and runoff components are reduced by 2% per ton of the mean annual rate of manure application, on a dry weight basis.

Interpretation of the P loss ratings

The P index risk value is the sum of the erosion and runoff components. The risk scores fall into four risk levels.

- Low (0-2). Current practices keep water quality impairment due to agricultural P pollution low. Manure can be applied at rates sufficient to meet crop N needs.
- Medium (2-5). Delivery of agricultural P may cause some water quality impairment and consideration should be given to alternative conservation and P management practices. Manure can be applied at rates sufficient to meet crop N needs.
- High (5-15). Phosphorus loss from the field causes much water quality impairment. Remedial action, such as alternative conservation measures or P management practices, is required. Manure can be applied, but P applied should not exceed crop P removal. Manure can be applied to meet a crop's N need but total P applied in one or more applications during a four year period should not exceed crop removal during that four year period.
- Very high (>15). Impairment of water quality is extreme and remedial action is urgently required. Phosphorus application should be discontinued. Improved conservation measures should be implemented.

Using the Nebraska P Index (2005)

Information is needed for each field or management unit within a field in order to calculate a P index value (Table 3; additional information may be needed to estimate erosion). The information may be obtained from the farm operator, records and reports, and observation. The information is entered into the white cells of the **Nebraska P index** worksheet. Values in yellow

boxes are calculated based on information entered in the white boxes or selected from drop-down lists. Phosphorus index values appear in the red boxes.

1. Select the **County** in which the field is located from a dropdown list. The P index then accesses relevant rainfall and soils information.
2. **Gross erosion** is next determined.
    a. Give an estimate of mean annual loss of soil to **Sheet & Rill** erosion for this field/management unit. The estimate might be determined using RUSLE 2 (http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm) or by other means, or obtained from the local NRCS office.
    b. Give estimates for ephemeral and gully erosion for the full management unit and the number of acres in the management unit. Clicking on **Estimate** next to **Ephemeral** provides guidance to estimating ephemeral erosion.
3. Select a relevant **Sediment Trap** practice such as terraces from the dropdown list.
4. The **Sediment Delivery** Ratio considers landform and distance.
    a. Select the correct part of Nebraska by clicking **View Map and Choose**, entering the number for the correct landform region, and clicking **Back** to return to the main worksheet.
    b. Enter distance in feet from the center of the management unit to either to surface water (an intermittent or perennial stream or lake, or a channel of concentrated flow lying outside the field, such as a road ditch, which delivers runoff directly to a water body; more details are provided in the associated **Note**.
5. Select the **Grassed Filter Strip Width** from the dropdown list.
6. The P **Enrichment** option, such as tillage, is selected from the dropdown list.
7. The **Runoff Curve Number**, the basis for estimating the volume of runoff, is determined from county rainfall, land use and soil type. County rainfall was accessed when **County** was selected.
    a. Select **Land Use** from the dropdown list.
    b. Select **Dominant Soil Type** from the dropdown list.
8. For soil test P, select **Phosphorus Test** method (Bray-P1, Mehlich 3, or Olsen) from the dropdown list and enter the P test result for the 0-8” depth.
9. Enter the mean annual **Application Rate** for P in fertilizer and organic materials, e.g. manure, compost, and bio-solids. Select the application time and method from the dropdown list.
10. Select **Type of Irrigation** from the dropdown list. If furrow is selected, enter **flow rate** and **furrow slope**.
11. Enter a value for **Manure Component**; see associated note.
12. Optional information can be entered at the top of the worksheet for your records: names of field name, option, person using the P index and the client.
13. The calculated partial P index values are given in yellow boxes for the **Erosion Component** and **Runoff Component.**
14. The overall **P Index Value** is given in the red box on the right hand side of the worksheet.
15. Click the **Summary** button to create a summary report. Click the **Summary** worksheet tab to go to this worksheet in order to view, save and print one or more summaries.

As stated above, operators of CAFOs are required, as of Dec. 31, 2006, to complete a risk assessment for each field receiving manure once every five years. Fortunately, once the data is entered into the spreadsheet for a field, the file can be saved with the name for that field, and only those variables that have changed, for example soil test P, need to be entered when the field is next evaluated.

Repeated scenarios can be run for a field with changes in management practices as a means of assessing the effectiveness of various management practices and combinations of practices. Each scenario is given a name and the data from the previous scenario can be carried forward so that only the variable or variables that are changed for the new scenario need to be entered. Detailed outputs for these scenarios are tabulated in a worksheet that can be saved and printed for further study.

An example of using the P index to compare management scenarios

Consider the information presented in Table 3 for a hypothetical field to create a base scenario. For the information given, the P index score is 7.9 with a risk rating of High. Let's consider the effects of several alternatives on the base scenario; after each change, return to the base scenario before making another change.

1. If manure application continues, and STP is increased to 160 ppm, the P index score is 10.04 with a risk rating of High.
2. If the land is protected with tile inlet terraces, the P index score is 1.00 with a risk rating of Low.
3. If 25 ft buffer strips are established between this field and concentrated water flow or the surface water body, the P index score is 7.35 with a risk rating of High.
4. If the manure is incorporated within 24 hours of application and assuming no increase in erosion, the P index score is 7.87 with a risk rating of High.
5. If distance from the middle of the sub-field to concentrated water flow is reduced from 300 to 75 ft, the P index score is 10.99 with a risk rating of High.

Table 1. Source and transport factors that contribute to the potential for P loss from agricultural lands to surface waters.

Site and management factors	**Transport factors**[1]
Soil P level P application practices including time, rate and method of application Field management practices such as tillage practices and use of cover crops	Runoff volume Erosion from rainfall and snowmelt events and from irrigation events Distance from P source to concentrated water flow or a water body

[1] Other possible transport factors that are not considered in the Nebraska P index include: surface and sub-surface drainage; percolation and under-ground movement of P to seepage areas; and atmospheric deposition that may be associated with wind erosion. These are relatively minor transport factors, as compared to runoff volume and erosion, for P delivery from fields to surface waters in Nebraska.

Table 2. Factor values for erosion risk with furrow irrigation.

Furrow flow rate / **Furrow slope**	**Soil Erodibility**											
	Very erodible soil[1]				**Erodible soil**[2]				**Erosion resistant soil**[3]			
	<0.5%	0.5-1.0 %	1.0 - 1.5%	>1.5 %	<0.5 %	0.5-1.0 %	1.0 - 1.5%	>1.5 %	<0.5 %	0.5 - 1.0 %	1.0 - 1.5 %	>1.5 %
Gallons/min	----------rating----------											
<5	1.5	1.5	12	12	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
10	1.5	12	12	12	1.5	1.5	6	6	1.5	1.5	3	3
15	12	12	12	12	1.5	6	6	6	1.5	3	3	3
>20	12	12	12	12	6	6	6	6	1.5	3	3	3
If irrigated field includes tail water pit with total recapture, use a rating of 0. If polyacrylamide (PAM) is used, use a rating of 1.5												

[1]Very erodible soils (silt, fine and very fine sandy loam, loamy fine sand, loam, and very fine sand soils)
[2]Erodible soils (silt loam soils)
[3]Erosion resistant soils (silty clay, clay, and clay loam soils)

Table 3. Form for collection of data required to run the P index. Assessment may be on a whole field basis or on management zones within fields.

Field name	Run	County	Field area (acres)	Erosion			Conservation practice	Distance to water or conc. flow	Filter strip width	Land use/ cropping system
				Sheet and rill	Gully (tons/field)	Ephemeral (tons/field)				
West 1/4	*1*	*Colfax*	*40*	*15 tons/ac*	*0*	*10*	*none*	*300*	*7*	*Row crops. tillage*

Soil type and slope	Soil P		P application		Sprinkler irrigation	Furrow irrigation				Mean manure application tons/yr, d. wt.
						Rate gpm	Furrow slope	PAM	Reuse pit	
	Test	ppm	(lbs P_2O_5)	Method						
Nora si cl l 2-6 %	*Bray*	*95*	*100*	*Surf. app.*	*No*	*No*	*No*	*No*	*No*	*10*